

## *Carbon Transport and Deposition in Tokamaks*

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**Motivation**—Carbon-based materials are commonly used for plasma facing components in tokamaks because of their ability to survive high transient heat loads. However, chemical erosion of such materials by the fusion plasma produces hydrocarbons which dissociate in the plasma boundary and redeposit elsewhere onto the vessel wall. In tritium fueled tokamaks, codeposition of tritium with carbon can lead to large inventories of retained tritium. Models to simulate erosion, transport and deposition are needed for design of fusion reactors and their operating conditions, which will avoid excessive tritium retention. However, the complexity of the physical processes necessitates experiments in tokamaks to guide the model development.

**Accomplishment**—Such experiments are being conducted at the DIII-D tokamak in San Diego in a collaboration between Sandia and General Atomics.  $^{13}\text{CH}_4$  is injected into lower single null plasmas as illustrated in Fig. 1. This plasma geometry, and location of injection far from the divertor, were chosen to simulate methane originating from plasma interactions with the graphite main chamber wall. Graphite tiles were subsequently removed and analyzed at Sandia to determine the spatial distribution of  $^{13}\text{C}$  deposition.  $^{13}\text{C}$  coverage was measured using  $^{13}\text{C}(^3\text{He,p})^{15}\text{N}$  nuclear reaction analysis. The experiment has now been conducted twice, the first time with low power low density (L-mode) plasmas and more recently with high power high density (H-mode) plasmas. These measurements show the  $^{13}\text{C}$  is deposited primarily at the divertor as shown in Fig. 2, with much lower  $^{13}\text{C}$  coverage elsewhere (not shown), though analysis of tiles outside the divertor region is still in progress for the second experiment.  $^{13}\text{C}$  deposition at the inner divertor is similar for these two plasma conditions.

Between the two strike points, deposition was low for L-mode but high for H-mode plasmas.

**Significance**—The results show that methane entering the plasma from the main chamber wall is not redeposited near its point of origin, as some models predicted, but instead is ionized and carried by the plasma to the divertor. The observed asymmetry between deposition at inner and outer divertors indicates that carbon is swept towards the inner divertor by a fast flow in the plasma boundary.

The difference in deposition between L-mode and H-mode results from the different plasma conditions in the divertor. With L-mode the divertor plasma is detached (low temperature, high density) at the inner leg but attached (high temperature, low density) at the outer leg. With H-mode the region of detached plasma includes both inner and outer legs of the divertor. Carbon deposition evidently occurs from detached divertor plasma, whereas erosion dominates where plasma is attached.

These results have important implications for the next large fusion energy research device, the International Thermonuclear Experimental Reactor (ITER). The single-null detached H-mode plasmas in DIII-D are similar to proposed ITER plasma conditions. Detached plasmas were chosen to reduce erosion and heat flux in the ITER divertor. The results from the DIII-D  $^{13}\text{C}$  injection experiments suggest that in ITER, hydrocarbons from the main chamber would deposit in the divertor contributing to the in-vessel tritium inventory. The choice to use a metal wall in ITER's main chamber will greatly reduce the rate of hydrocarbon production and hence reduce the rate of tritium retention thereby allowing more efficient use of tritium and extending the operational life of the device.

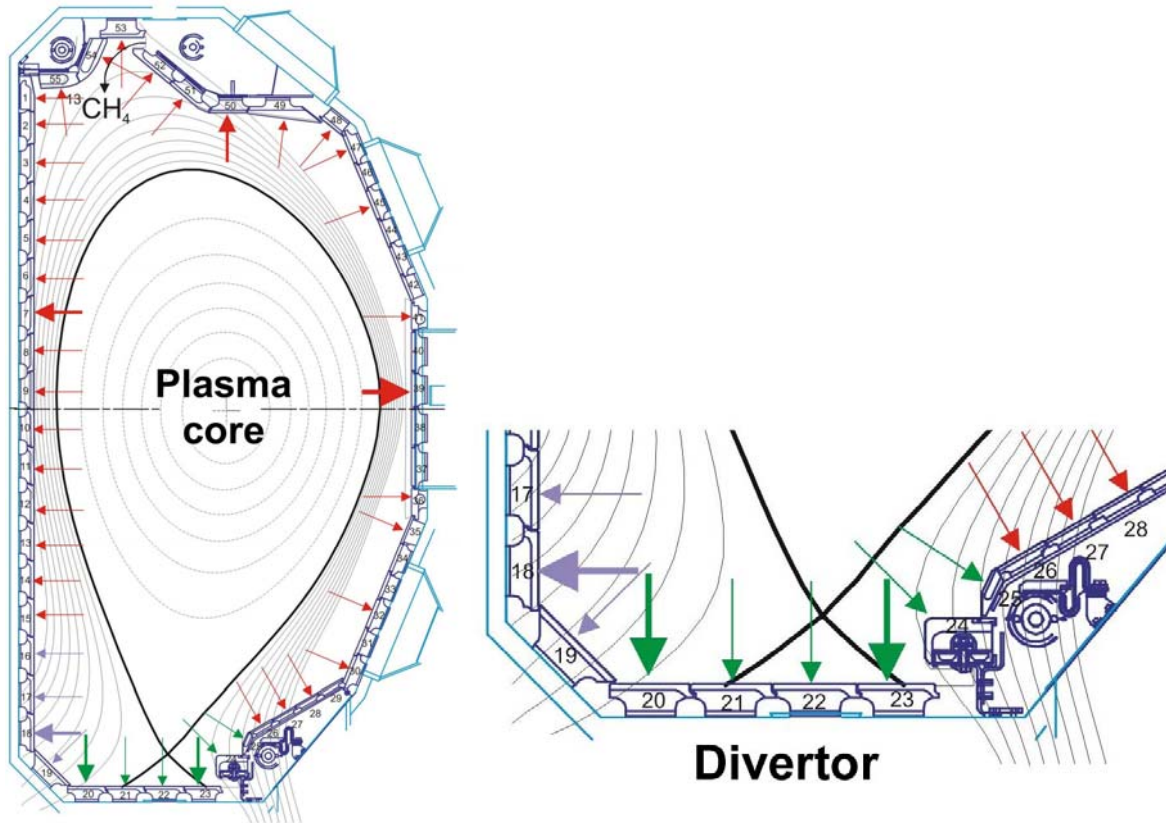
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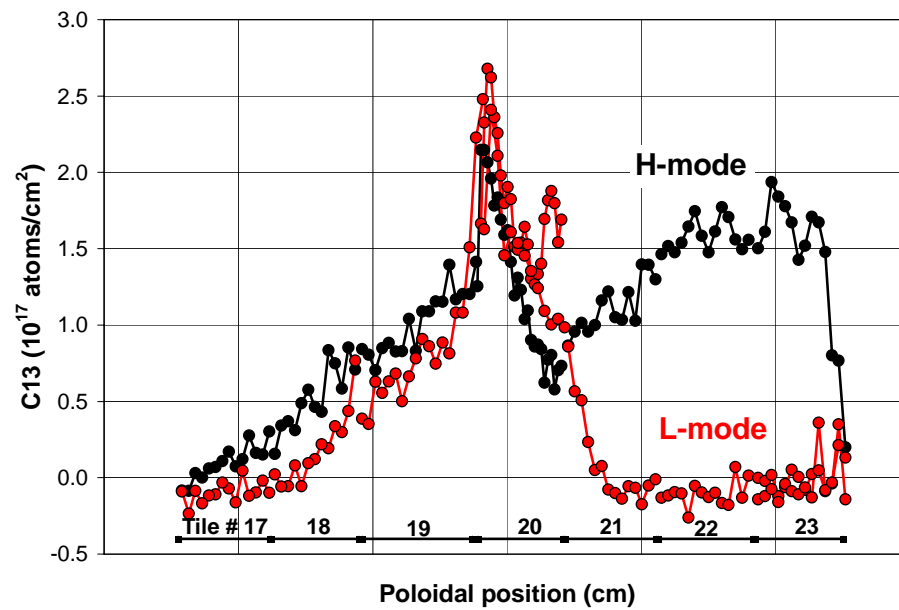
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**Figure 1.** Diagram of the DIII-D tokamak with lower single null plasma configuration.  $^{13}\text{CH}_4$  is injected at the top of the main chamber. The heavy black line shows the last closed magnetic flux surface. Boundary plasma flows along outer field lines which intersect surfaces in the divertor.



**Figure 2.** Measured coverage of carbon 13 in the divertor region.